The Effect of Skeletal Form on Second Molar Impaction

by

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Background: Mandibular second molar impaction, while still a relatively rare condition, has been increasing in frequency over recent years. There are a few theories about what might be causing these impactions, including, lower arch crowding[1], genetics[2], and use of appliances that preserve E-space[3], such as lower lingual holding arches and lip bumpers[4]. A potential contributor to second molar impaction that has not been studied is skeletal form. The purpose of this study was to examine the relationship of gonial angle to the impaction of mandibular second molars. Secondary goals were to compare second molar tooth size, space available, ramus to molar width, and the angle between the occlusal plane and posterior border (OP-PR) of the mandible in patients with impacted second molars and those without. **Hypothesis:** Patients with mandibular second molar impaction are more likely to have a smaller gonial angle when compared with patients that do not have impaction. **Materials and Methods:** Panoramic radiographs were collected from two private orthodontic offices. Those with impactions were designated to the experimental group, while those without were designated to the control group. Measurements were made on each of the radiographs and compared between experimental and control groups. **Results:** No statistically significant difference was found in gonial angle between impacted and non-impacted groups. Statistically significant differences were found for space available ratio, ramus to molar width ratio, and OP-PR angle between the two groups. **Conclusions:** There was a clinically significant difference in the tooth size to space available ratio between the two groups with the second molar accounting for 126% of the space available in the impacted group and only about 80% of the space available in the non-impacted group. A clinically significant difference was also found in OP-PR between the two groups, with the impacted group averaging 72.43º, and the non-impacted group averaging 66.39º. These findings may be of use to clinicians when treatment planning for patients that have the potential to develop second molar impactions.

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Preface

I would like to thank Dr. Robert Mortimer for the original idea for this project, as well as his guidance and assistance throughout the entire research process. I would also like to thank Dr. David Spokane along with Dr. Robert Mortimer for contributing the radiographs and patient information that was used for this project. Thank you to Dr. John Burnheimer for leading my research committee and assisting me throughout the entire research process. Thank you to Dr. Nilesh Shah for his guidance and recommendations for data collection and statistical analysis. Finally, I would like to thank Alexa Spokane for assisting me in collecting patient radiographs as well as assisting in data collection.

1.0 Introduction and Statement of the Problem

In recent history, clinicians have noticed a trend of an increased number of patients with impacted second molars[1]. In a cross-sectional study performed by Evans, it was shown that there was an increase in second molar impaction in orthodontic patients over a 10-year period, and that lower arch crowding was the most consistent finding within the impacted group[1]. While there have been a few proposed theories, the etiology of second molar impaction remains unclear. A retrospective study by Ferro collected data on orthodontic patients with lower crowding [4]. The experimental group in this study was treated with lip bumpers to prevent mesial drifting of the permanent first molar, and suggested that this may be a potential cause for second molar impaction[4]. Another study, performed by Sonis, et. al looked at the preservation of E-space in two hundred patients and found that second molar impaction was increased in those that received space maintainers when compared to those that did not, again implicating the prevention of mesial drift in second molar impaction cases [3]. A study performed by Shapira, et. al, suggests a genetic component in second molar impactions, with a greater prevalence in a Chinese-American population when compared to a commensurate Israeli population [2]. There are multiple studies that have shown a connection between vertical condylar growth and third molar impaction [5-8]. These studies suggest that an increased vertical condylar growth pattern leads to decrease in gonial angle, and therefore smaller resulting space between mandibular second molar and anterior border of the ramus [5, 6]. While such studies have been done on third molar impaction, current research lacks investigation into the effect of skeletal form on second molar impaction. The aim of this study will be to determine whether or not skeletal form has an effect on second mandibular molar impaction and if so, what that effect may be.

2.0 Specific Aims

Aim 1. Collect gonial angle measurements from panoramic radiographs along with measurements of space available for second molars for two groups of patients: those with impacted second molars (experimental group) and those without (control group). Measurements of second molar tooth size, ramus to molar width, and the angle between the occlusal plane and posterior border of the mandible (abbreviated as OP-PR) will also be measured.

Aim 2. Perform statistical analysis to compare the variables listed above (gonial angle, space available, ramus to molar width, OP-PR) in experimental group vs. control group.

Aim 3. Examine any relationship found between gonial angle, space available, ramus to molar width, OP-PR, and impaction status.

Aim 4. Determine if the findings from this study may have an effect on clinical decision making in patients that have the potential for second molar impaction.

3.0 Background and Literature Review

3.1 Incidence of Second Molar Impaction

In general, second molar impaction is a rare phenomenon. The incidence lies between 0.6/1000 and 3/1000 [9, 10]. In an epidemiological study by Aitasala et al., it was found that in a population sample of 4063, 14.1% had one or more impactions, but that less than 1% of these impactions were first and second molars [11]. Varpio found a prevalence of impaction of second molars to be 0.15% in a Swedish population [10], while Johnsen found a prevalence of 0.3% in an American population [12]. One study found a prevalence of 2.3% in general eruption disturbance of second molars with a 0.2% incidence of second molar impaction [13], while Cassetta et al. found a prevalence of 1.36% of impacted second molars in a population of white orthodontic patients [14]. In more recent studies, Fu found a 0.65% impaction prevalence in a Taiwanese population [15] and Cho found a 1% prevalence of impacted second molars in a Chinese population [16]. While the incidence of second molar impaction is generally uncommon, it seems that it has been increasing in recent years. In a study by Evans, a three-fold increase in the incidence of second molar impactions was found over a ten-year period[1]. Impactions in this study of 400 total patients increased from 2% to 7% incidence from 1976 to 1986 [1].

3.2 Etiology of Molar Impactions

Knowledge about the etiology of second molar impaction is based mainly on case reports and a few clinical studies [17]. Many studies have cited crowding as an etiologic factor [1, 4, 10, 18, 19]. Genetics have also been thought to play a role. In a study by Shapira, panoramic radiographs of 3,500 Israeli patients and 3,000 Chinese-American patients were assessed, and it was concluded that second molar impaction demonstrates a moderate genetic trait. The prevalence of second molar impaction in Chinese-Americans was almost twice that found in Israelis. It appeared that this was an autosomal trait, as there was no prevailing sex, and there was right-left asymmetry present, but with no side preference. In cases where patients had a unilateral impaction, they found a shorter distance between the first molar and the anteroposterior rim of the ramus, shorter vertical distance between the second and third molar, greater mesial inclination of the impacted second molar and of the third molar, undersized length of the mesial root of the impacted second molar, and a greater difference in length between the distal and mesial roots of the impacted second molar [2]. In a study of 1520 patients, Baccetti found a possible additive genetic effect in the phenotypic expression of failure of first and second molar eruption [20].

In addition to a genetic component Varpio et al. found that follicular cysts, supernumerary teeth, fibrotic gingiva, and complicated root anatomy played a role in second molar impaction [10]. Raghoebar found that physical barriers, an abnormal eruption path, supernumerary teeth, odontogenic tumors, idiopathic factors, and inadequate arch length contributed to these impactions [21]. Cassetta et al. also found that a smaller distance between the first molar and ramus contributed to second molar impaction [19]. Related to the finding that a smaller distance between first molar and ramus has an effect on second molar impaction, studies have shown that the use of a lip bumper and general preservation of E-space can decrease space available for the second molars and therefore increase the chances of impaction [3, 4]. Another finding that was consistent across various studies was that high or mesial angulation of the second molar increased likelihood of impaction [1, 3, 9, 19].

Few studies have compared skeletal factors and impaction of mandibular second molars, but Cassetta et al., in a study of 248 patients, did find that vertical condylar growth was among the skeletal features found in patients with second molar impaction [14]. Additionally Vedtofte et al. studied the panoramic and cephalometric radiographs of 19 patients and found that a smaller gonial angle, class II skeletal relationship, and dental and root anomalies were associated with impaction of second molars [9]

3.3 Diagnosis of second molar impaction

Failure of a second molar to erupt is typically an asymptomatic pathology and is frequently an incidental finding [22]. Impaction has been defined by Evans as a tooth that has abnormal contact with a tooth in the same arch [1]. Cassetta et al. described the phenomenon as a tooth in which the complete eruption to occlusal height was prevented by an abnormal contact with another tooth in the same arch or remained unerupted during the time it should have emerged [14]. The Sonis and Ackerman definition states that the tooth is impacted if the occlusal plane of the mandibular second molar is below the cementoenamel junction of the adjacent mandibular first molar [3]. Many studies consider a tooth to be impacted by following the Raghoebar definition, which states that a tooth is impacted when there has been a cessation of eruption caused by a clinically or radiographically detectable physical barrier in the eruption path or due to an abnormal position of the tooth [21].

3.4 Treatment and Outcomes

There are multiple different ways to address the treatment of impacted second molars. Buchner suggests the extraction of premolars to relieve crowding and then performing orthodontic up righting [18], while Cho et al. suggests observing for 12 months to see if the condition spontaneously corrects. In the cases where self-correction does not happen, Cho considers one of four options [16]. The first is orthodontic up righting, which will ideally take place in early adolescence to take advantage of incomplete root formation, as shown by Shapira et al. [23]. The second option is surgical up righting, which was shown to be a successful treatment by McAboy et al. and Shipper and Thomadakis [24] [25]. The third option that Cho suggests is extraction of the second molar, allowing the third molar to drift mesially. And the final option is extraction of the second molar and transplantation of the third molar into the extraction site [16].

Valmaseda-Castellon et al. showed that treatment for impacted second molars was successful only 50% of the time. Their study included 43 patients, that underwent various treatment methods, depending on the severity of impaction. They concluded that if neither an early diagnosis is established, nor an early treatment provided, loss of the molar or absence of function was the most common final result [26]. In a study done by Fu, 96 patients underwent orthodontic up righting. The treatment was found to be effective with predictable success and also lead to natural improvement of infrabony defects, leading to a healthy periodontium [15]. Magnusson and Kjellberg found that in their study of 87 patients, more than half of the treatments rendered for correction of second molar impaction failed. They found extraction of the third molar to be least successful (11%), although it was the most common treatment, while surgical exposure was the best choice, with a 70% success rate. They additionally concluded that intervention before root formation was important in increasing the number of successful treatments [17]. It seems that in general, orthodontic treatment, surgical exposure, or a combination of both, combined with early diagnosis is important in order to start treatment of second molar impaction at the right time and to limit potential complications [21].

3.5 Facial Form and Gonial Angle

In orthodontics, the vertical relationships in the face are just as important as the horizontal and sagittal. This is because the treatment plan, as well as the outcome, is affected by the vertical relationships and the growth pattern of the patient. The gonial angle is widely used in orthodontic cephalogram tracing. It is typically measured by taking the tangent to the posterior border of the ramus and the tangent to the lower border of the mandible and is one of the most important parameters giving an indication about the vertical relationship and symmetry of the facial skeleton [27]. Gonial angle is also a valuable indicator to diagnose the growth patterns of patients and can determine the rotation of the mandible [28]. Rubika, et al. performed a study aimed to evaluate the gonial angle as an indicator for a patient's growth pattern. This study was conducted on the lateral cephalograms of 90 patients, and gonial angle was measured along with upper gonial angle and lower gonial angle. The upper and lower angles were created by splitting the gonial angle via a line from nasion to gonion. The study concluded that the upper gonial angle was the same, irrespective of growth pattern, but that the lower gonial angle increases from horizontal, to average, to vertical growth patterns. All of the values found in the study were statistically significant and the authors therefore concluded that both gonial angle and lower gonial angle can be used as an indicator for growth pattern [28].

Typically, a large gonial angle indicates more of a tendency for posterior rotation of the mandible, with condylar growth directed posteriorly[29]. A small gonial angle indicates vertical growth of the condyles, leading to a tendency toward anterior rotation with growth of the mandible[29]. The mean value for the gonial angle is 128° ± 7°[29]. When divided into upper and lower gonial angles, a large upper angle (58°-65°) suggests horizontal growth changes, while a larger lower angle indicates vertical growth[29]. The magnitude of the gonial angle is determined by the relation between anterior face height and the length of the ramus[29]. With an increase in anterior face height, the gonial angle tends to be obtuse, while with a small anterior face height, the angle tends to be more acute[29]. In general, greater anterior face height is correlated with a larger gonial angle [29]. In a study by Xiao, et al. of 69 Chinese patients, it was concluded that high angle patients exhibited increased vertical hyperdivergency along with increased gonial and lower gonial angles. The low angle group showed significant hypodivergence with decreased values for gonial and lower gonial angles. Essentially, the patients with downward and backward rotation of the mandible were considered to be high angle and they showed increased gonial angle, while the patients with an upward and forward direction of the mandible were considered to be low angle and they showed a decrease in gonial angle [30].

In a study by Jensen et al., it was determined that the size of the gonial angle is associated with the proportion between facial height and ramus height. With a relatively greater facial height, the angle is more obtuse (as in open bites) and conversely, with a smaller facial height, it is more acute (as in deep overbites). He also stated that according to Keiffer, “individuals with short and broad faces have a smaller angle than individuals with a long and narrow face. The size of the gonial angle is associated with the proportion between facial height and ramus height. With a relatively greater facial height, the angle is more obtuse and with a relatively smaller facial height is more acute"[31, 32].

While gonial angle has been traditionally measured using cephalometric radiographs, Mattila et al. did a study using panoramic and cephalometric radiographs from 601 patients that showed that gonial angle measurements were similar using both radiographic methods. The study demonstrated that the gonial angle can be measured from a panoramic radiograph with the same degree of accuracy as it can from a cephalometric radiograph. The study also concluded that right and left gonial angles can be easily determined individually from the panoramic radiograph, avoiding superimposed images found on cephalograms. This proves that the panoramic radiograph is the more obvious choice for determining gonial angle measurements [27].

4.0 Purpose of the Present Investigation

The purpose of this investigation is to evaluate the relationship, if one exists, between impaction of mandibular second molars and skeletal factors. Gonial angle, tooth size, space available for mandibular second molars, ramus to molar width, and the angle between the occlusal plane and the posterior border of the ramus (OP-PR) were measured in a sample of orthodontic patients with and without impacted second molars. The primary hypothesis is that patients with mandibular second molar impaction are more likely to have a smaller gonial angle when compared with patients that do not have impaction. The secondary hypotheses are that patients with mandibular second molar impaction are more likely to have less space available when compared with the size of the second molar, a larger ramus to molar width, and a larger OP-PR when compared with patients that do not have impaction. The null hypotheses for all of the variables is that there is no difference between impacted and non-impacted groups.

5.0 Materials and Methods

5.1 Sample

Panoramic radiographs were collected from two private orthodontic offices. These radiographs were taken at the initial record collection appointment for each patient. Inclusion criteria for the study included patients that are from ages 9-16 with panoramic radiographs. Exclusion criteria included patients with craniofacial anomalies/syndromes, previous orthodontic treatment, or missing mandibular second molars. The radiographs were evaluated for the presence of impacted second molars, identified by cessation of eruption caused by a clinically or radiographically detectable physical barrier in the eruption path or due to an abnormal position of the tooth (the Raghoebar definition[21]). Those with impactions were designated to the experimental group, while those without were designated to the control group. Sample size was calculated with a power of 80%, alpha of 0.05 and a meaningful difference of 7°, as 7° is one standard deviation for gonial angle. The sample size needed to sufficiently power this study was 18 patients per group. A total of 20 patients were selected for each group. Investigators were unable to be blinded as to which patients were assigned to each group, due to the nature of the investigation.

5.2 Data Acquisition

After designation into experimental and study groups, measurements were made to determine gonial angle, tooth size, space available for mandibular second molars, ramus to molar width, and OP-PR. This was done using a simple ruler and protractor measuring tool on MiPACS software. Because these measurements were taken on panoramic radiographs, we were unable to account for differing magnifications of the images. Therefore, the linear measurements were converted into ratios (tooth size : space available and tooth size : ramus to molar width). The measurements were taken by two separate investigators and a random sample was re-measured 6 weeks later to insure intra-rater reliability.

Gonial angle measurement was taken by measuring the angle between a line drawn tangent to the posterior border of the ramus and a second line tangent to the lower border of the mandible. The occlusal plane was then established by drawing a line tangent to the cusp tips of the mandibular first molar. The measurement for space available was made by drawing a line from the distal height of contour of the first molar to the anterior border of the ramus, parallel to the occlusal plane. Tooth size was measured from the mesial height of contour to the distal height of contour of the second molar. Ramus to molar width was measured from the distal height of contour of the first molar to the posterior border of the ramus, parallel to the occlusal plane. OP-PR was the angle between the occlusal plane and the line tangent to the posterior border of the ramus (Figure 1).

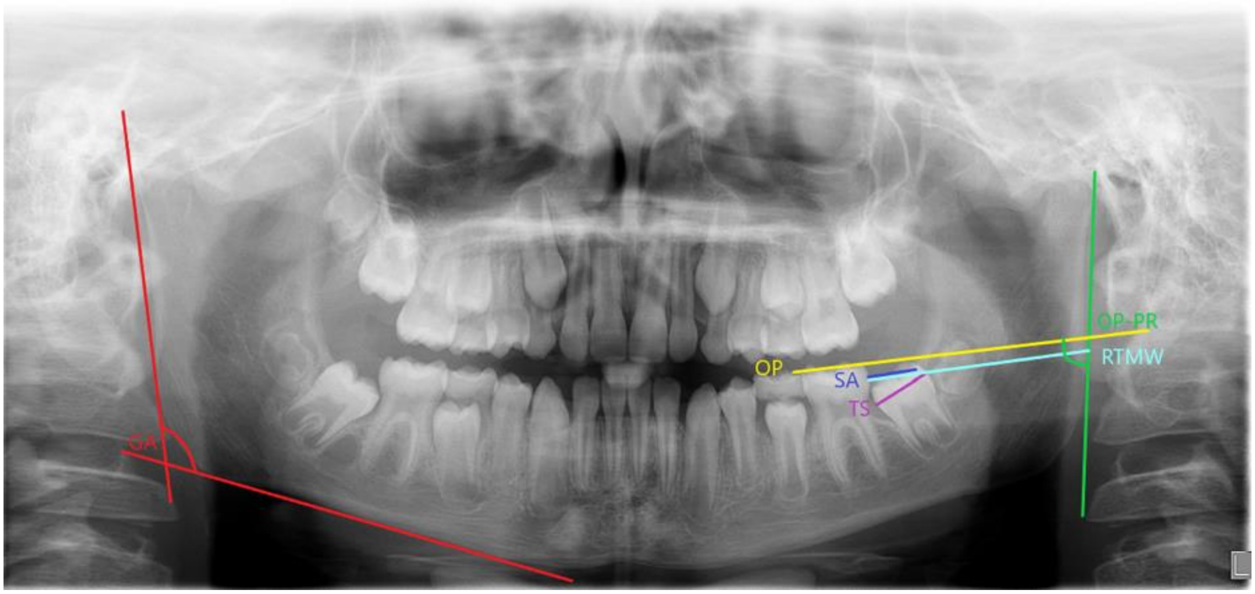

Figure 1.

Pictured here are the measurements that were taken on each panoramic radiograph. GA (red) shows the gonial angle. OP (yellow) is the line demarking the occlusal plane. SA (dark blue) is space available. TS (purple) is tooth size. RTMW (light blue) is ramus to molar width. And finally, OP-PR, the occlusal plane to posterior ramus angle is indicated by the green arc.

5.3 Statistical Methods

Sample size was calculated to be 18 patients per group for a power of 80%, alpha of 0.05, and a meaningful difference of 7º. A chi square test was done to determine the difference between the sex in the impaction and non-impaction groups. Two-Sample t-tests were done to determine the differences between age, gonial angle, tooth size to space available ratio, tooth size to ramus to molar width ratio, and OP-PR in the impaction and non-impaction groups. Intraclass correlations were calculated to determine intra- and inter-rater reliabilities. All statistical analysis was done using Stata/SE 15.1 software.

6.0 Results

20 subjects were selected for each group (impacted and non-impacted). 17 males and 23 females were included in the study (Table 1). 9 patients presented with bilaterally impacted second molars, while 5 patients presented with right sided impactions only, and 6 patients presented with left sided impactions only. The average age of the subjects was 12.5 years old, ranging from 9-14.5 years. Average age for the impacted group was 12.43 and for the non-impacted group the average age was 12.76 (Table 2). The average gonial angle measurement in this study was 122.75°. For patients with impacted second molars the average gonial angle was 121.98° and for those without impacted molars the average gonial angle measurement was 123.52° (Table 2). The average space available ratio (tooth size : space available) in this study was 0.97. The average for impacted teeth was 1.26, indicating space deficiency, and 0.80 for non-impacted teeth, indicating an excess of space (Table 2). Average ramus to molar width ratio (tooth size : ramus to molar width) in the study was 0.26, 0.27 for patients with impacted teeth, and 0.24 for patients without impactions (Table 2). Finally, the average OP-PR in this study was 69.41°, 72.43° for patients with impactions, and 66.39° for those without (Table 2).

After comparing the averages for all of these measurements, the data was split into right and left sides. This was done because not all patients had bilateral impactions. The data showed that the gonial angle average was 122.25° on the right side, with an average of 120.89 in the impacted group and 122.98 in the non-impacted group. The gonial angle average was 123.25° on the left side, with the impacted group averaging 123.55 and 123.07 in the non-impacted group. The space available ratio was an average of 0.97 on the right side, 1.26 in the impacted group and

0.81 in the non-impacted group. The average was 0.97 on the left side, again 1.26 in the impacted group and 0.79 in the non-impacted group. Ramus to molar width ratio was 0.25 on the right, with an average of 0.27 in the impacted group and 0.24 in the non-impacted group. Ramus to molar width ratio was an average of 0.26 on the left, 0.29 in the impacted group and 0.25 in the non-impacted group. Average OP-PR on the right side was 69.65°, with an average of 73.66 in the impacted group and 67.5 in the non-impacted group. OP-PR angle was an average of 69.17° on the left, with an average of 73.77 in the impacted group and 66.41 in the non-impacted group (Table 3).

No statistically significant difference between impacted and non-impacted groups for was found for sex (Table 1), age, average gonial angle (Table 2), gonial angle on the right side, or gonial angle on the left side (Table 3).

However, statistically significant differences between impacted and non-impacted groups were found for average tooth size to space available ratio, tooth size to space available ratio on the right side, tooth size to space available ratio on the left side, average tooth size to ramus to molar width ratio, tooth size to ramus to molar width ratio on the right side, tooth size to ramus to molar width ratio on the left side, and average OP-PR, OP-PR on the right side, and OP-PR on the left side (Tables 2 and 3).

Intra- and inter-rater reliabilities were assessed. Intra-rater reliability for one rater was 0.984 and 0.862, which indicates that both raters had good intra-rater reliability. Inter-rater reliability was calculated to be 0.962.

Table 1 Comparison of impacted and non-impacted groups in relation to sex

Sex comparison				
	Impacted	**Non-Impacted**	**Total**	**p value**
Male	8	9	17	0.749
Female	12	11	23	
Total	20	20	40	

Table 2 Comparison of average measurements between impacted and non-impacted groups

Comparison of patient's average measurements in impacted vs. non-impacted groups							
	Mean	**Std. Dev.**	**Impacted**	**Non-Impacted**	**Max**	**Min**	**p Value**
Age	12.60	1.15	12.43	12.76	14.58	9.17	0.3562
Gonial Angle	122.75	6.61	121.98	123.52	137.34	110.51	0.4687
Space Ratio	0.9688	0.2716	1.2617	0.8020	1.9486	0.5886	0.0000*
Ramus Ratio	0.2553	0.02876	0.2686	0.2419	0.3385	0.2024	0.0022*
OP-PR	69.4129	6.5436	72.43	66.39	90.04	55.6675	0.0024*

(* indicates a statistically significant difference, with a p value of <0.05)

Table 3 Comparison of separate right and left side measurements between impacted and non-impacted groups

Comparison of each side's measurements (R and L) in impacted vs. non-impacted groups							
	Mean	**Std. Dev**	**Impacted**	**Non-Impacted**	**Max**	**Min**	**p Value**
Gonial Angle (R)	122.25	6.61	120.89	122.98	139.66	109.99	0.5408
Gonial Angle (L)	123.25	7.09	123.55	123.07	137.58	109.82	0.4345
Space Ratio (R)	0.9706	0.2845	1.2604	0.8146	1.9987	0.6004	0.0000*
Space Ratio (L)	0.9670	0.3107	1.2631	0.7894	1.9948	0.5767	0.0000*
Ramus Ratio (R)	0.2529	0.0304	0.2763	0.2404	0.3224	0.1953	0.0201*
Ramus Ratio (L)	0.2576	0.0314	0.2780	0.2453	0.3545	0.2034	0.0009*
OP-PR (R)	69.65	6.8487	73.66	67.50	86.185	56.67	0.0397*
OP-PR (L)	69.17	7.3951	73.77	66.41	93.895	54.67	0.0005*

(* indicates a statistically significant difference, with p value of <0.05)

7.0 Discussion

The results show that comparisons of gonial angle did not have any statistical significance between impacted and non-impacted groups. There was however, a slight difference in the average gonial angle between the two groups, with the impacted group having an average angle of 121.98° and the non-impacted group having an average angle of 123.52°. With a difference of about 1.5°, the impacted group did have a smaller gonial angle on average, but this result is neither statistically or clinically significant. This finding leads us to fail to reject our null hypothesis that there would be no difference between the gonial angles of the impacted group vs. the non-impacted group. This finding does not agree with Vedtofte et al., who found that a smaller gonial angle was associated with the impaction of second molars[9]. It is interesting to note that in general, the average measurement for gonial angle is 128°±7°, but in our study, the average gonial angle measurement was 122.75. While this measurement does fall within one standard deviation of the norm, and therefore is not statistically significant, this may indicate a general trend of smaller gonial angles in today's patients when compared with those studied to set the standards are still in current use. This topic may be of interest for future studies.

The ratio comparing the size of the mandibular second molar and the space available was larger in the impacted group (1.2618) when compared with the non-impacted group (0.8020) and this difference was statistically significant. A larger ratio indicates that the tooth is taking up a larger portion of the space available. In this study, on average, in impacted patients, the tooth size accounted for 126.18% of the space available, while in the non-impacted group the tooth size was 80.20% of the space available, a clinically significant difference. This finding corroborates earlier studies[19], suggesting that there is less space available in cases with impacted teeth and leads to the conclusion that a tooth is more likely to erupt if there is sufficient space for it. We therefore reject the null hypothesis. This finding is also significant in that if the clinician is able to identify a second molar that is greater than or equal to 100% of the space available, they may be able to diagnose, and therefore treat the impending impaction early, which is important for a successful outcome[17, 21, 26].

Findings for the ramus to molar width ratio were similar to those found for the space available ratio. There was a statistically significant difference between the two groups, with a larger average ratio in the impacted group (0.2686), compared with the average ratio in the non-impacted group (0.2419), leading us to reject the null hypothesis. Again, a larger ratio indicates that the tooth is taking up a larger portion of the distance from the first molar to the posterior border of the ramus, and in this case, in the impacted group, the second molar accounted for 26.86% of the space from the distal height of contour of the first molar to the posterior border of the ramus, while in the non-impacted group, the tooth accounted for 24.19% of the space. This may indicate a larger ramus thickness in impacted patients when compared with patients without second molar impaction. While this is a statistically significant finding, a 2.67% difference is not clinically significant. Therefore, this finding, while interesting, is not of particular use to the clinician.

The occlusal plane to posterior ramus angle measurements showed a significant difference between impacted and non-impacted groups, leading us to again reject the null hypothesis. On average, the OP-PR in impacted patients was 72.43º, while the average was 66.39º in non-impacted patients. This finding shows that in general, patients with a flatter or more distally inclined occlusal plane in reference to the posterior border of the mandibular ramus, sometimes seen in deep bites, are more likely to have an impacted second molar than a patient with a steeper or more mesially tipped occlusal plane in reference to the posterior border, as sometimes seen in open bites. This finding leads to the conclusion that because the first molar is taking up more area at the plane of occlusion, there is less room for second molar to come in, leading to impaction. With an average difference of about 6% between the impacted and non-impacted groups, this finding is clinically significant. Using this information as a diagnostic tool may again help the clinician in earlier diagnosis of second molar impaction, and therefore lead to earlier intervention.

The commonality between the statistically significant findings in this study is that they all suggest insufficient space available for the erupting second molar. This is consistent with the finding of Cassetta et al. that there is a smaller distance between the first molar and the anterior ramus in cases of second molar impaction[19]. The exclusion criteria of this study included patients with previous orthodontic treatment. Therefore, none of the patients in the study had lip bumper therapy or any preservation of the E-space. The findings of Ferro et al. and Sonis et al. suggest that these treatments may have further increased the chance for impaction in these patients[3, 4]. This information is useful for the clinician to inform his or her decision about whether or not to use these treatment modalities. Based on the findings of this study, when treatment planning for patients with a large tooth size to space available ratio, a large ramus width to molar ratio, and a large OP-PR angle, the clinician should consider the possibility of increased chance for impaction when weighing the risks and benefits of lip bumper and other preservation of E-space treatments. In cases with crowding that are on the borderline of extraction vs. non-extraction treatment, the findings from this study may be of use when determining the path forward. If the patient has the characteristics indicating second molar impaction, the clinician may be more amenable to an extraction treatment plan to allow for future eruption of the second molars. This option would address the crowding with premolar extraction instead of using lip bumper or E-space preservation appliances.

As shown by Valmaseda-Castellon et al., treatment of second molar impaction was successful only 50% of the time and if there was neither an early diagnosis, nor an early treatment provided, the loss of the molar or absence of function was the most common final result[26]. The findings in this study of increased tooth size to space available ratio, increased ramus to molar width ratio, and increased OP-PR may be used in addition to other diagnostic tools to determine early diagnosis for impaction of second molars. With an earlier diagnosis of second molar impaction, earlier treatment can take place, which will hopefully lead to more successful outcomes. While there are many different approaches to treatment of second molar impaction, Magnusson and Kjellberg found that surgical exposure was the best choice, with a 70% success rate and that intervention before root formation was an important factor for increasing the number of successful treatments [17]. Another successful treatment option that may be considered, particularly in patients with mandibular crowding, is the extraction of premolars to relieve some of the crowding and then orthodontic uprighting of the second molar[18]. Again, using the findings from this study may be useful in earlier diagnoses, earlier treatment, and therefore, more successful treatment outcomes.

8.0 Limitations

Due to the retrospective nature of this study, we were unable to gather any clinical measurements from the patients, including amount of crowding or the clinical size of the first molars, which could have been used to account for magnification error between the different radiographs. Because of the use of panoramic radiographs, we were unable to make accurate linear measurements due to magnification error. This issue was accounted for by the use of ratios (tooth size : space available and tooth size : ramus to molar width).

9.0 Future Studies

As mentioned previously, the findings from this study may help clinicians to determine which treatment option to move forward with when considering extraction vs. non-extraction treatment plans in borderline cases. Future studies about early intervention in these borderline cases with likely second molar impaction are needed in order to say whether or not the findings in this study can be used as diagnostic tools.

Previous studies have shown that high or mesial angulation of the second molar increased the likelihood of impaction, but have not discussed the role of the angulation of the first molar in second molar impaction cases[1, 3, 9, 19]. This study showed a flatter or more distally tipped occlusal plane when compared with the posterior border of the ramus. This would indicate an upright or even distal angulation of the first molar, which may lead to limited space for second molar eruption, leading to second molar impaction. This phenomenon may also be a good topic for future studies to explore. In addition to indicating an upright or distal angulation of the first molar, a flatter occlusal plane can also be an indication of a deep bite. The findings in this study may suggest that patients with deeper bites are more likely to have second molar impaction, but this again, would need to be confirmed in a future study.

As previously stated. The average gonial angle measurement is 128°±7°, but in our study the average gonial angle was 122.75°. While still within one standard deviation for gonial angle measurement, it is an interesting finding that our average gonial angle is about 5° smaller than the norm. Future studies could investigate the gonial angle over time to determine if there is a secular trend toward a smaller gonial angle.

10.0 Conclusions

1. There was no statistically significant difference found between gonial angle measurements in impacted and non-impacted groups.
2. There was a statistically significant difference in the space available ratio, ramus to molar width ratio, and the occlusal plane to posterior ramus angle between impacted and non-impacted groups.
3. There was a clinically significant difference in the tooth size to space available ratio between the two groups, with the second molar accounting for 126% of the space available in the impacted group and only accounting for about 80% of the space available in the non-impacted group.
4. A clinically significant difference was also found in OP-PR between the two groups, with the impacted group averaging 72.43º, and the non-impacted group averaging 66.39º.
5. These findings may be of use to clinicians when treatment planning for patients that have the potential to develop second molar impactions, but this conclusion should be confirmed by future studies.

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